out at the flank of the towering head and may rise upward over the latter. At times the veil-like St. may be elevated throughout an extensive region by the underlying turbulent stratum so that it has the appearance from a greater height of a smooth stratus sheet in which the Cu. are embedded as soft fountain-like forms.

In airplane observations it is often necessary to penetrate a uniformly dense, formless cloud mass more than 4,000 meters thick, when frequently it is impossible to see the tips of the wings of the airplane. An extreme case of this kind occurred on January 2, 1930, when upon descending, the airplane entered the cloud at 5,000 meters elevation and emerged from it at about 50 meters above the ground. Such enormous cloud formations appear nearly always to be associated with the passage of a "wind convergence."

During one flight to 7,000 meters elevation, an opportunity was afforded to observe Ci. at close range. The impression obtained was that massive fall-stripes (Fallstreifen) are formed from Ci. clouds and that they (Ci.) are composed of ice crystals.

During a night flight in the autumn of 1928 the gleam of light from the city appeared on the cloud surface with great clearness.

It was occasionally found that the starting of the airplane motor caused the "ripping open of a lane" in a ground fog.

In Cu. of turbulence it was found that the rows ran mostly in long streaks some hundreds of meters apart, parallel to one another, nearly in the direction of the wind. These rows often exhibited cross-rippling.

Although flights within or under the "squall roll" are to be avoided, some flights were started shortly before an oncoming squall. It was found that over a breadth of 3 to 5 kilometers in front of the "squall roll" there exists a strong vertical bumpiness, which disappears, however, directly above the "squall roll." The area behind the "squall head" is, likewise, free from bumpiness.

It was found to be very difficult to estimate correctly the height of clouds from the ground and to judge their vertical extent from their appearance. In a uniform stratus layer, the visibility horizontally and vertically downward sometimes vanishes immediately on entering the cloud, while at other times the ground is visible for a long time through the cloud mass. This may be due to the size and number of the cloud droplets. From a study of fog, being made at the Deutsche Seewarte, it has been found that fog droplets may be regarded as smooth, opaque little disks and, therefore the visibility varies according to the number and radius of the droplets, with the same vapor content of the air.[2]

[2] A drop of any given radius is equivalent in mass to 8 drops of half that radius, while its equatorial cross section is half the sum of the similar cross sections of the 8 small drops. Hence the interference of the 1 large drop, to a beam of light is just half that of the equivalent 8, except in so far as 2 or more of the latter may chance to be along the same line of sight. Clearly then, for any given mass of water in droplet form (fog or cloud) betweeen observer and object, the visibility increases roughly as the radius of the droplets.—ED.

SHOWER AND DRIZZLE

By W. J. HUMPHREYS

Of course everyone knows what a shower is and what a drizzle is too, until he tries to define them. For our present purpose, which is to consider how each is produced, and what therefore under given circumstances it probably signifies, we shall define a shower as a rain of brief duration of medium-sized to large drops; and a drizzle as a very light rain, usually more or less persistent, of quite small drops. If the drops are as much as one twenty-fifth of an inch in diameter, or larger, surely they do not constitute a drizzle, but rain, and fall with a velocity of, roughly, 10 to 25 feet per second, as determined by the size of the drop and density of the air through which they are falling. They can not fall faster than around 25 feet per second because if, and as soon as, through coalescence or otherwise, they become large enough to fall with a greater speed they at once are torn to pieces by the drag of the air through which they are passing. But the rate of fall, whatever it be, is of course, with reference to the air and therefore not at all necessarily the speed of approach toward the surface of the earth. The two velocities, that is, the rate of fall through the air and the rate of approach toward the surface of the earth, are the same only when there is no vertical movement of the air through which the drops are falling. Wherever, then, the upbrush of the air is equal to, or greater than, the rate of fall of the drops through such atmosphere, that particular precipitation can not approach closer to, much less reach, the surface. Of course the greater the height and, consequently, the rarer the air, the greater its upward velocity must be, and in proportion to the decrease of density, to sustain drops of a given size.

Only the largest possible raindrop, one fifth of an inch in diameter, falls through still air of average sea level density at the uniform rate of 25 feet per second. The drops of a moderate rain, as that term is commonly used, having a diameter of, roughly, one twenty-fifth of an inch, have a velocity of fall of about 12 feet per second. Drizzle drops, so small that it would take about 125 of them to span an inch, fall only some two and a quarter feet per second, while cloud droplets, 1,200 of which would stretch barely one inch, fall only one twenty-fifth of a foot, or thereabouts, per second, or 144 feet in the course of an hour.

From the foregoing it is clear that for each given velocity of ascent of the air there is a corresponding minimum size of raindrop that can get through it to lower levels. Smaller drops can not fall while the appreciably larger ones must and do. Hence ascending air carries cloud droplets up and keeps them up until by further condensation, coalescence, or both together, they have grown large enough to overcome the lift of the rising air, whereupon, but *not* until they have so grown, they fall to the earth.

If appreciably rising air carries cloud droplets up, as it certainly does, one asks then how it is that the cloud itself, base and all, is not lifted to greater heights. The explanation is that while the individual droplets are lifted to greater levels fresh cloud is continuously formed in the uprising air as soon as, through expansion, incident to increase of height, it has cooled to its dew point, or saturation temperature. The individual particles are carried up, but continuously replaced by freshly-formed droplets at the same cloudbase level. And if the ascent is gentle the droplets soon are evaporated a little way above in the drier air and no rain is formed.

A drizzle, then, or very gentle rain of quite small drops, occurs only where there is little or no ascent of the air—two and a half feet per second at most. A shower, on the other hand, which consists of relatively large drops, requires for its production vertical convection of considerable strength. Furthermore, the shower covers, at any instant, only a rather limited region because the air obviously can not be going up everywhere at the same time over a wide area. Hence also it is of short duration. A persistent rain of largish drops can happen only where the cause of the convection, such as a mountain across the path of the wind, is enduring and fixed in position. But such a rain is not a shower.

So much for the difference between the ways in which drizzles and showers are formed. It will be interesting now to inquire what circumstances lead to vertical convections of the air such as give showers, and what to drizzle rains in which clearly there is but little or no convection. Whether or not marked convection will develop depends on the vertical distribution of temperature, mainly, and to some extent also on that of water vapor, for increase of humidity decreases the density of the air just as does increase of temperature. Convection not only can, but must, ensue wherever and whenever the surface of the earth is considerably warmed (by sunshine chiefly) since it in turn then correspondingly heats the lower air which thereupon expands and becomes lighter. This is the origin of the heat thunderstorm so common in the Tropics and adjacent regions. Where condensation occurs in such cases latent heat of vaporization is rendered sensible and the convection thereby still further accentuated, as is evident from the great height to which the cumulus cloud often towers.

Another way by which the vertical contrast of temperature essential to convection is established is by the importation of colder air above. Still another is the wedging in of cold air under warm air. Both of these ways, overrunning and underrunning, occur along the cold front, or windshift line, and often in such vigorous manner as to produce severe squalls. Still another way of inducing vertical convection, commonly moderate and therefore productive usually of rather gentle showers, is by the gradual heating of the under layer or portion of cool air as it drifts over a surface that becomes increasingly warm with the distance traveled. This applies perfectly to a broad deep mass of air of polar origin drifting equatorward over an ocean. Here, and often on land as well, the showers are indicative of the origin (polar) of the air in which they are occurring.

On the other hand, the lower portion of a current of air of tropical origin moving over the ocean, say, or land either, to higher latitudes, tends to become progressively colder and colder, and thereby so stable that local convection in it is quite impossible. After a time the dew point may be passed with the formation of fog and low cloud out of which a drizzle, light to heavy, may fall, but never a shower, there being no vertical convection, except that small amount incident to the turbulence caused by surface friction.

We therefore are assured that such rains as occur within polar air as it advances equatorward are quite likely to be of the shower type and, conversely, that showers often are convincing evidence that the passing air is of polar origin. Similarly, tropical air moving poleward may afford a drizzle long before a mountain, or a barrier of cold air, is encountered. Also a drizzle is evidence of tropical air on its way to higher latitudes.

Showers evidence the presence of marked vertical convection; drizzle proves the absence of such convection. Showers often indicate the equatorward passing of polar air; drizzle the presence of poleward-moving tropical air. Thus shower and drizzle are well nigh rain extremes—in size of drops, rate of precipitation, nature of origin, and their meteorological significance.

METEOROLOGY AND THE FOREST FIRE PROBLEM

By S. B. SHOW

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Foresters have always recognized the importance of the relationship between weather and forest fires in the West. For a number of years after organized fire suppression was instituted, the relative importance of the various weather factors upon fire suppression during the fire season was unknown, or at best, guessed at. Even in these early days it was generally recognized that occasionally in every fire season there occurred short periods of one or several days when the forest cover was unusually inflammable and at times seemed almost explosive. These periods frequently produced greater damage, burned over area, and suppression costs than the remaining 95 per cent of the fire season. This being so, it was essential that attempts be made to determine the factors that brought about these dangerous periods. It was recognized, of course, that abnormal weather conditions were responsible for these periods, but which of the meteorological conditions were most responsible was unknown to foresters. Obviously, the study of the influencing factors was the first needed step to be undertaken in the solution of this problem.

Accordingly, from 1915 to 1925 this phase of the problem was the subject of several independent studies by various members of the Forest Service in the important fire regions, aiming to supplement the work of the Weather Bureau. The main objective was the determination of the principal climatic causes of the sudden changes in the inflammability of forest fuels.

It was found that during the fire season, for some of the most inflammable of our forest types, wind velocity and direction and relative humidity are the most important meteorological factors affecting the spread of a fire. With wind remaining the same, relative humidity is an exceedingly important factor in controlling the size of fires; the lower the humidity, the greater the size. Similarly, with relative humidity constant, there is an increase in size of fires as the wind velocity increases. The critical periods of explosive inflammability always occur when very low relative humidity occurs together with a high wind velocity. Neither low relative humidity nor high wind velocity alone has resulted in such a high rate of spread as the combination of these two factors. The effect of changes in wind direction on fire control endeavor is obvious.

The prediction of these periods and of their duration is of utmost importance to those engaged in forest fire control. The Weather Bureau began its fire-weather warning service in 1916 in California, and has, year by year, consistently enlarged and improved this service. In 1926 a special fire weather official was assigned to the California district which coincides with Region 5 of the Forest Service. Since that time substantial progress has been made in laying the ground work for systematic fire weather forecasting and increasingly valuable information has been furnished the field officers of the protection agencies. Many special observation points are